

Comparative analysis of traditional power supply and operation of solar panels in protected ground systems

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Abstract. This article discusses the issues of autonomous power supply of the greenhouse. The types of greenhouses and their main microclimate parameters are considered. The article calculates the payback of installing solar panels on a greenhouse and the usual power supply of a greenhouse, depending on its type. As a result, it was revealed that the installation of solar panels has advantageous advantages in comparison with traditional mains power

1 Introduction

The greenhouse must maintain a certain microclimate, which is necessary for growing plants inside it. All this requires certain costs, which should not exceed, in the long term, the costs of its maintenance and power supply. As already mentioned, greenhouses have several types – seasonal and year-round.

The problem of creating greenhouse complexes is the lack of favorable parameters for growing plants all year round. This is due to different environmental parameters, which directly depend on the duration of plant cultivation. The main parameters are air temperature, daylight duration and humidity in the greenhouse. These parameters change over the course of the year, and the main task of the greenhouse complex is to maintain them within favorable limits, which are reflected in the GOST for the cultivation of a certain crop [1].

All this requires electricity to create favorable conditions, and, accordingly, financial costs. In order to reduce energy costs, not traditional energy sources are needed, but alternative ones, the main types of which include wind generators and solar panels [2].

With the introduction of these alternative sources of electricity, the greenhouse complexes no longer depends on traditional electricity, but becomes an autonomous object that can be installed on any territory located remotely from traditional sources.

The creation of autonomous agricultural facilities is currently an urgent task in accordance with the State Policy for the Development of Alternative Energy [3].

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2 Materials and methods

Let's take a closer look at the parameters and systems used in greenhouses.

Watering is an important process of greenhouse operation. For the proper functioning of the irrigation system, a pumping station with an expansion tank is required, the engine power of which is taken from 350 W. For the greenhouse under study, we accept the electricity consumption of the received station, 4 W/m².

Ventilation can be of different types. These can be vents that open from the drives, or they can be fans. For the calculation, we will take an axial fan that works for movement and for mixing the air inside the greenhouse with an electricity consumption of 2-3 W/m².

The next parameter is heating. There are several types of heating: water, air, or IR heating (it is also electric). To choose the right heating devices, you need to take into account the heat loss that each greenhouse has. To do this, the power is selected, which ensures the maintenance of the temperature inside (e.g. +20 °C) and the exposure to external temperatures (e.g. -25 °C). After that, it is necessary to calculate the heat loss at a temperature difference $\Delta t = 45$ °C, i.e. how much the greenhouse will lose, and the power required for the heating elements to operate at this power is laid.

With water heating, the main units are pumps that create pressure directly into the system. To do this, you need to lay pumps that will create such an amount of water with a coolant (usually +70-80°C) so that the heat received from them is given to heating devices. Let 's give an example: 5 fan heaters are installed on a greenhouse of 10x50 m. For each fan heater, you need to lay 1 pump with a capacity of about 5 m³, or with a capacity of 150-200 W. Based on the above, we put up to 5 W/m² on pumps [4].

If there is air heating (a boiler that heats the air), then you need to lay 10 W/ m².

The third heating option, the most energy-consuming, is electric heating. In this case, the main source of heat is infrared heaters, for the full operation of which requires the power of the system, which would provide 200 W/m². Usually this method of heating is used in greenhouses up to 100 m², where heating with IR heaters is still advisable because of their energy consumption.

This is followed by a parameter such as lighting. Lighting is the most energy-consuming part of the greenhouse operation. There are several types of artificial lighting: sodium floodlights, or LED floodlights. To use classical sodium floodlights, it is required to lay down a power of about 80 W/m².

It is more expedient to use LED spotlights. Depending on the diodes that are used (different luminosity and different light flow), a power of 20-60 W/m² is laid for diodes of various types of production. Based on the calculations, high-quality LEDs are 3 times more economical than sodium spotlights, therefore, we will install diodes in the greenhouse under study, which will have a power of up to 20 W/m² [5].

After studying all the parameters, their pros and cons, we will calculate the cost of electricity in a greenhouse powered by a network and compare the values obtained with the cost of installing and operating solar panels.

3 Results

For the calculation, we take the following parameters:

- Greenhouse with an area of $S = 500$ m².
- We will accept the electricity tariff of 3.96 RUB/kWh.
- For irrigation, we install a pumping station (consumption 4 W/m²).
- For ventilation, we install fan heaters (consumption 3 W/m²).
- For heating, we take water heating (consumption 5 W/m²).
- For lighting, we use LEDs (consumption 20 W/m²).

The capacities are laid taking into account the maximum consumption of electricity by greenhouse systems.

We will calculate the electricity costs of our greenhouse per day, per month, per year. To do this, add up all the capacities and multiply them by the electricity tariff set in the greenhouse region (in our case, this is the Rostov region, Russia). All calculations are performed automatically using a program written in Microsoft Excel. The values obtained are shown in Table 1.

Table 1. Calculation results.

Indicator	Day	Month	Year
Costs, RUB	1663.2	49896	598752
Power consumption, kWh	420	12600	151200

As can be seen from the calculations, the maximum total power consumed by the greenhouse per day is 420 kWh/day. Let's move on to the calculation of solar stations.

For the calculation we will need the following data:

- The level of insolation in the region.
- Current electricity tariffs.
- The volume of electricity consumption by the greenhouse.
- Station equipment.

The level of insolation can be determined by looking at the solar atlas. [6] It allows you to select any region of the world, the type of system and the rated power of solar panels, and the system will automatically determine the level of insolation. Based on our data, the level of insolation in the Rostov region is $I_{sp} = 6.2$ MWh/year.

The electricity tariff was adopted equal to 3.96 RUB/kWh.

Now let's calculate the average actual hourly volume of electricity consumption according to formula 1:

$$G = \frac{12600 / 30}{16} = 26,3 \text{ kWh.} \tag{1}$$

Where: G - average actual hourly consumption, kWh; V - meter readings for the month, kWh; n - number of days in a month, days; n_1 - number of daytime hours, hours/days. Daytime hours are calculated based on the tariff zones of the day approved by the FAS of Russia. In all subjects of the Russian Federation it is 16 hours [7].

Based on all the calculations and the data obtained, we will select the appropriate equipment. We choose the equipment according to capacity. Since our greenhouse consumes 26.3 kWh on average per hour, it is necessary to know the value of output per hour. Of the 24 hours in a day, on average, only 12 are light. This time is from 6 am to 6 pm — more in summer, less in winter. It turns out 4380 hours a year. Divide the value by insolation, 6100 kWh, by the number of light hours - and we get that a 5 kW panel will produce 1.4 kWh per hour. Now it is necessary to select our values for the production of panels up to the average consumption level obtained in the calculations — 26.3 kWh per hour.

To do this, multiply in turn by 2,3,5, etc., until we get a value close to 26.3, but slightly lower. In our case, $18 \cdot 1.4 = 25.2 \text{ kW} < 26.3 \text{ kW}$ and we get that an 18 kW solar panel is required for proper operation.

Choosing by price, we select the appropriate panel. The supplier is Hevel, a grid station with a power of $P_{ct} = 20 \text{ kW}$, costing 1151190 RUB, excluding installation — this is 10-15% of the cost of the station. The service life of the panels is 30 years [8].

Now we calculate the effect.

To calculate the effect, it is necessary to know the average cost of generating a kilowatt-hour of the selected solar station over its entire service life.

To do this:

- The full cost of the solar station is calculated: 1151190 RUB +115119 RUB for installation. We get $C_o = 1266309$ RUB.
- Next, we will calculate the output volume of the station for the entire service life according to formula 2:

$$O = I_{sp} \cdot P_{ct}, \quad O = 6100 \cdot 20 = 122000 \text{ kWh.} \quad (2)$$

Where: I_{sp} – the value of insolation, kWh per year; P_{ct} – the power of the solar station, kW.

The output volume is 122000 kWh. For 30 years — 3,660,000 kWh.

- The payback period is calculated according to formula 3:

$$D = \frac{C_o}{(O \cdot c)}, \quad D = \frac{1266309}{122000 \cdot 3,96} = 2,6 \text{ years.} \quad (3)$$

4 Discussion

Summing up the calculations, we can make an unambiguous conclusion that despite the annual increase in electricity tariffs, the annual slight decrease in the efficiency of the plant's generation, the hourly operation of the equipment of the greenhouse itself showed that the installation of solar panels is profitable. [9]

It should also be remembered: the more powerful the solar station, the cheaper the output of each kWh.

In most subjects of the Russian Federation, there is enough sunlight to install solar stations.

Every year the expediency of installing solar stations in Russia is increasing: prices are rising, and stations are getting cheaper. [10]

For legal entities, the installation of solar stations is more expedient than for individuals, because of the price difference.

It is impractical to put solar stations in the country if you do not live there permanently. This will seriously increase the payback period.

To save on electricity, it is worth considering network solar stations without batteries. The batteries in the solar stations allow them to be used as a backup energy source, but it will not be possible to save money on such stations.

To take advantage of the legislation on microgeneration, it is necessary to officially connect the station to the networks and conclude an agreement with a sales organization.

5 Conclusion

According to the calculation results, we get that our solar station will pay off in less than 3 years, and, given the current realities of the economic situation at the moment, this is a good result and has the right to be used in real conditions.

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